

# UNCLASSIFIED

AD NUMBER
AD861455
NEW LIMITATION CHANGE
TO Approved for public release, distribution unlimited
FROM Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; APR 1969. Other requests shall be referred to Commanding Officer, Edgewood Arsenal, Attn: SMUEA-RPR, Edgewood Arsenal, MD 21010.
AUTHORITY
USAEA ltr, 15 Mar 1971

THIS PAGE IS UNCLASSIFIED

AD 861455

VAPOR PHASE IMPREGNATION OF ACTIVE CARBONS

Quarterly Progress Report No. 1

January Through March 1969

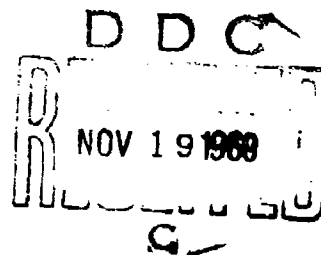
D. Marshall Andrews  
John P. Redmond

April 1969



DEPARTMENT OF THE ARMY  
EDGEWOOD ARSENAL  
Physical Research Laboratory  
Edgewood Arsenal, Maryland 21010

Contract DAAA15-69-C-0302



COMMONWEALTH SCIENTIFIC CORPORATION  
500 Pendleton Street  
Alexandria, Virginia 22314

Reproduced by the  
CLEARINGHOUSE  
for Federal Scientific & Technical  
Information Springfield Va 22151

ADDITIONAL TO	
WFOI	WHITE SECTION <input type="checkbox"/>
ADC	DIFF SECTION <input checked="" type="checkbox"/>
UNANNOUNCED	<input type="checkbox"/>
JUSTIFICATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	
DIST.	AVAIL. AND
2	

### DISTRIBUTION STATEMENT

This document is subject to special export controls and each transmittal to foreign nationals or foreign governments may be made only with prior approval of the CO, Edgewood Arsenal, ATTN: SM:UEA-RPR, Edgewood Arsenal, Maryland 21010

### DISCLAIMER

The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

### DISPOSITION

Destroy this report when no longer needed. Do not return it to the originator.

VAPOR PHASE IMPREGNATION OF ACTIVE CARBONS

Quarterly Progress Report No. 1

January Through March 1969

by

D. Marshall Andrews  
John P. Redmond

April 1969

DEPARTMENT OF THE ARMY  
EDGEWOOD ARSENAL  
Physical Research Laboratory  
Edgewood Arsenal, Maryland 21010

Contract DAAA15-69-C-0302  
Project 1B662706A095

This document is subject to special export controls and each transmittal to foreign nationals or foreign governments may be made only with prior approval of the CO, Edgewood Arsenal, ATTN: SMUEA-TSTI-T, Edgewood Arsenal, Maryland 21010

COMMONWEALTH SCIENTIFIC CORPORATION  
500 Pendleton Street  
Alexandria, Virginia

## FOREWORD

The work described in this report was authorized under Project IB662706A095, CB Physical Protection Investigations (u). This report covers work completed in the period January to March 1969.

Reproduction of this document in whole or in part is prohibited except with permission of CO, Edgewood Arsenal, Attn: SMUEA RPR, Edgewood Arsenal, Maryland 21010, however, Documentation Center is authorized to reproduce the document for U. S. Government purposes.

The information in this document has not been cleared for release to the general public.

## SUMMARY

The purpose of this program is to study methods for the vapor deposition of metals and metal salts into the pores of activated carbons, and evaluate properties imparted to the carbons for toxic gas removal by this method of impregnation.

Work in the first phase of this program, part of which is covered by this report, is concerned with copper and chromium vapor phase impregnation studies.

A successful method for the vapor deposition of copper within the carbon pores using copper acetylacetonate as the reactant was developed and samples containing 8%, 4%, 2% and 1/2% copper by weight were prepared using PCC grade CWS carbon. Tests were run on these samples to determine their characteristics.

A technique was developed for the vapor impregnation of activated carbon with chromium trioxide through the ammonolysis or hydrolysis of chromyl chloride which had previously been adsorbed on the carbon. Samples were prepared by this method on carbons which had already been impregnated with copper. Analytical tests performed on the samples showed that chromium was present on the carbon in the +6 oxidation state and copper in the +2 state. The emission spectrograph analysis indicated the metals were present in the predicted concentration range.

## TABLE OF CONTENTS

	PAGE NO.
INTRODUCTION	7
APPROACH	8
SAMPLE TESTING	8
Analytical Tests	8
Surface Area Tests	9
Detoxification Tests	9
COPPER IMPREGNATION	9
CrO <sub>3</sub> IMPREGNATION	13
SAMPLE PREPARATION AND TESTING	15
CONCLUSIONS AND RECOMMENDATIONS	17
BIBLIOGRAPHY	19
APPENDIX	21
DISTRIBUTION LISTS	23
DOCUMENT CONTROL DATA - R&D, DD FORM 1473, with ABSTRACT AND KEYWORD LIST	25

Quarterly Progress Report No. 1

to

Edgewood Arsenal, Maryland

on

VAPOR IMPREGNATION OF ACTIVE CARBONS

INTRODUCTION

The usefulness of activated carbon as a detoxifying agent because of its relatively high absorption capacity is well known. Activated carbons, however, retain the toxic gases primarily by physical adsorption, and desorption results in recontamination of the air by the toxic compound. Efforts to correct this resulted in the impregnation of carbons with various metals and metal salts which have the ability to catalyze the decomposition or rearrangement of the toxic species into a less toxic material.

Generally, impregnation with metals and metal salts is achieved by a liquid process wherein the carbon is immersed in a water solution containing salts of the catalytic species. Subsequent drying of the carbon results in deposition of the catalyst on the carbon surface. This method does not allow for the full utilization of the carbon, since deposition occurs only in those pores into which the impregnating solution can penetrate.

This program is aimed at optimizing the catalytic activity of impregnated carbons by depositing a thin, uniform film of catalyst over the entire area of the carbon by a vapor deposition process. Essentially, this process consists of passing a volatile compound containing the desired metal into the pores of the carbon and subsequently decomposing the reactant by various means to deposit the catalyst. This technique should result in a finely divided, uniform and highly active catalyst.



## APPROACH

During the first quarter, work was focused on the deposition of copper and chrome by vapor impregnation methods to produce a carbon having CK activity equal to or better than ASC whetlerite. At Edgewood Arsenal previous work with ASC carbons showed that copper is most likely present in the catalyst as cupric oxide, and chrome is present in the +6 state. Those processes were studied which deposited the metals either in this form, or in a form which could be easily converted to the proper one. For the deposition of copper, the metal-organic copper acetylacetonate was chosen. This material has been the subject of patents for vapor plating copper.<sup>2</sup> The compound has a melting point of about 230°C and decomposes into copper and acetylacetone above 240°C. Although this process deposits copper as the metal, subsequent treatments with oxidizers converts it to the necessary oxide.

Three methods were chosen for the deposition of chromium. The metal can be deposited from dicumene chromium, a metal organic which decomposes above 300°C to yield chromium and cumene.<sup>3</sup> The chromium can be oxidized to the +6 state by subsequent treatments. The second method consists of vacuum sublimation of  $\text{CrO}_3$  into the pores of the carbon. For the third method, chromyl chloride is vaporized under vacuum and adsorbed into the carbon. Controlled hydrolysis of the compound then produces  $\text{CrO}_3$  and HCL.

## SAMPLE TESTING

Carbons prepared under this program will be subjected to three types of tests to determine their respective properties. These include analytical tests, surface area and pore size measurements and detoxification tests. Results of these tests are not complete as of this writing, and will be reported later.

### Analytical Tests

Simple qualitative analytical tests are used to determine the presence of the catalysts on the carbon. These would comprise the following tests:

1. Treat the impregnated carbon with  $\text{NH}_4\text{OH}$  - a deep blue solution indicates +2 copper.
2. Treat  $\text{NH}_4\text{OH}$  extract with lead nitrate - yellow ppt. indicates +6 chrome.

In addition, emission spectrographic analysis are used semi-quantitatively to determine the amount of catalyst present, and X-ray diffraction studies are being made to determine the molecular composition of the catalyst.

### Surface Area Tests

The effect of the catalyst on the total surface area of the carbon will be determined from nitrogen adsorption isotherms using the standard BET data plot. Calculation of pore-size distribution will be made from these data using the procedure devised by Cranston.<sup>4</sup> These calculations will aid in determining catalyst uniformity and penetration. The scanning electron microscope will be used also to view the coating inside the pores of the carbon.

### Detoxification Tests

Samples of impregnated carbons will be submitted to Edgewood Arsenal for testing of activity against toxic agents. Test with CK (CNCL) will determine the effectiveness of copper and chrome vapor impregnated carbons as compared to ASC whetlerites. Evaluation with PS ( $\text{CCL}_3\text{NO}_3$ ) will indicate any drop in carbon surface activity brought about by vapor impregnation.

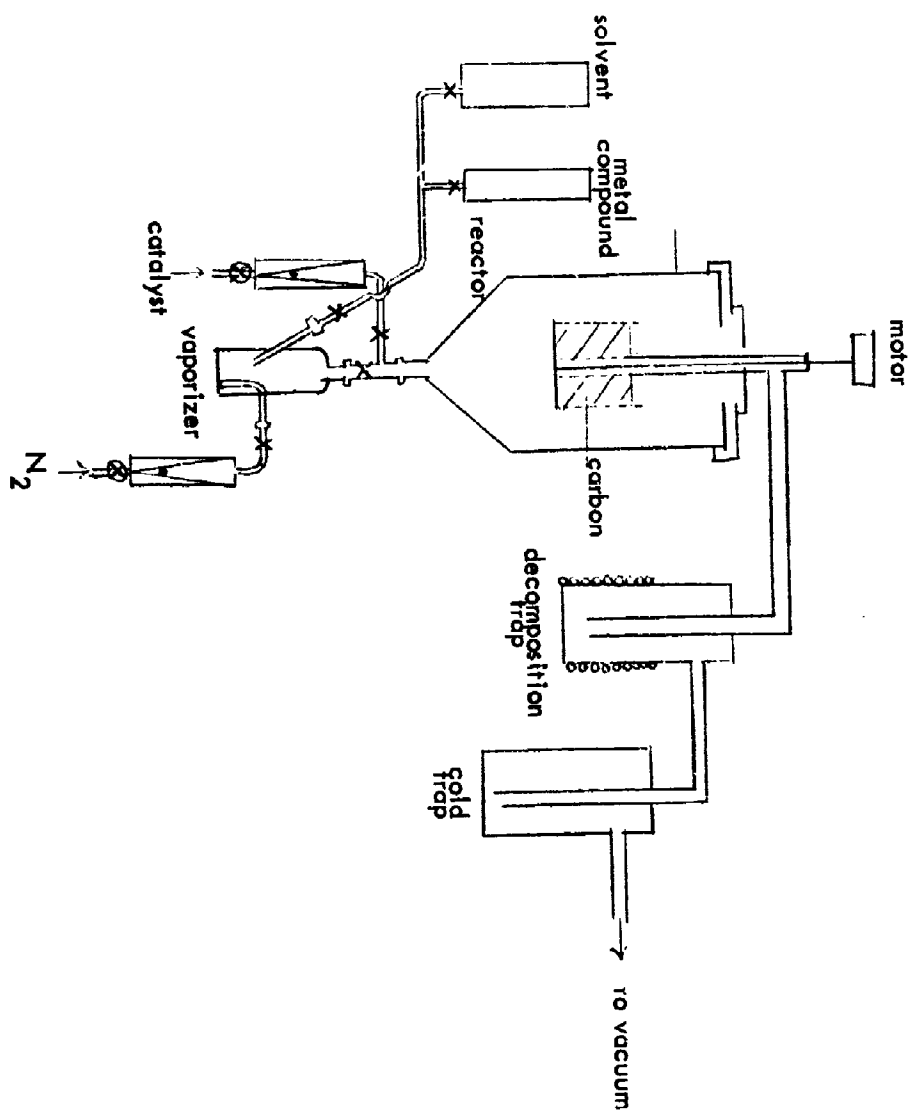
### COPPER IMPREGNATION

Most vapor deposition processes are basically the same unit operations, therefore, a system was designed which could be used for several of the processes planned in this program. [See fig. 1]. Carbon placed in the basket is heated by resistance or induction, and continually mixed by the rotating action of the basket. The metal containing compound is vaporized into the reactor where it must pass through the carbon to exhaust. A heated decomposition chamber and a dry ice cold trap prevent harmful exhaust gases from entering the vacuum pump. Measured amounts of catalyst may be introduced into the system in order to induce decomposition.

Several difficulties appeared in the first copper impregnation runs made with copper acetylacetonate. Although the system performed well for the most part, the small temperature range between vaporization and decomposition of this compound caused large amounts to decompose without ever leaving the vaporizer. Most of the material which did vaporize, then condensed out on the reactor walls even though these walls were heated. These experiments did show however, that carbon has a strong affinity for copper acetylacetonate, since the small amount which did reach the carbon was readily adsorbed.

In order to take advantage of this affinity, it was decided to dry mix the carbon and the copper acetylacetonate (CuAA) and heat the mixture under vacuum. This procedure would minimize the distance a molecule of CuAA vapor must travel before contacting the carbon, and thus reduce the possibility of its decomposing or condensing elsewhere. The first runs using this procedure proved to be successful. At a temperature of about  $70^\circ\text{C}$  and a pressure of 150u, all of the CuAA has been adsorbed into the carbon as evidenced by the disappearance of the blue colored CuAA. Decomposition of the organo-metallic begins at a carbon temperature of about  $100^\circ\text{C}$  with a pressure of 150u. The rate of decomposition continues to increase without any loss of reactant up to about  $200^\circ\text{C}$  and 350u. At these conditions, the occurrence of sublimation out of the carbon is evidence by condensation of material on the cool neck of the reaction flask.

FIGURE 1



GENERAL VAPOR DEPOSITION APPARATUS

Several runs made using this method, resulted in the following procedure for vapor impregnating carbon with copper from CuAA.

#### I Outgas Carbon

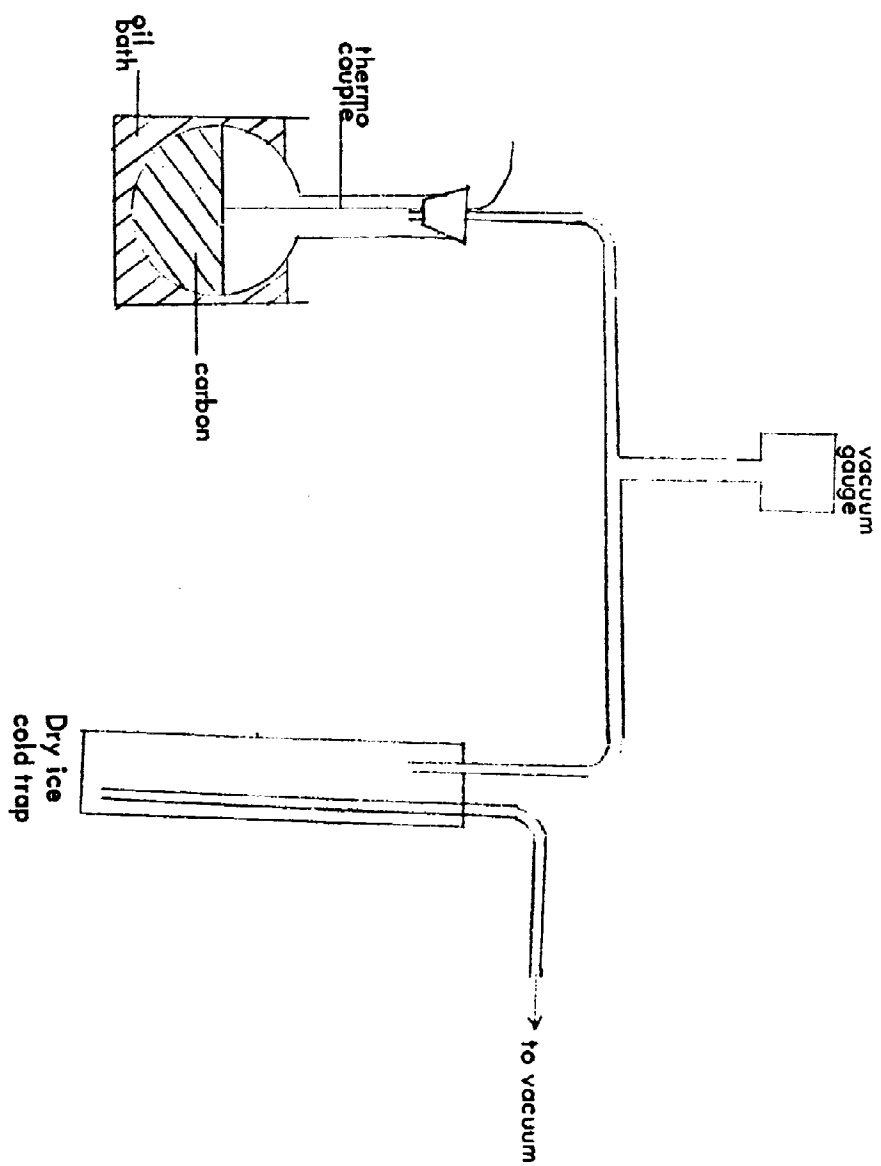
- (a) weigh into a round bottom flask of known tare the quantity of carbon to be impregnated (not to exceed 1/2 the volume of the flask).
- (b) connect the flask to the vacuum system [Fig. 2] and begin evacuating
- (c) turn on oil bath. Heat and set control for  $300^{\circ}\text{C}$
- (d) keep a record of temperature and pressure variations
- (e) when pressure is less than 250u for a carbon temperature of  $275^{\circ}\text{C}$ , turn off heat
- (f) when carbon temperature drops below  $150^{\circ}\text{C}$ , return system to atmospheric pressure
- (g) reweigh carbon and determine weight loss

#### II Impregnate Carbon

- (a) to the flask containing the carbon from Part I, add the amount of CuAA to give the desired weight percent of copper [CuAA is 24.3% Cu by weight] therefore, it requires four times the weight of CuAA to obtain a given weight percent Cu, i.e., for a 100 gm sample of carbon add 16 gm CuAA to get a 4% by wt copper impregnation
- (b) Shake the flask to intimately mix the carbon and CuAA
- (c) connect flask to vacuum system [Same as Fig. 2] and begin pump down
- (d) when pressure drops below 500u, turn on heat and set for  $100^{\circ}\text{C}$
- (e) keep a record of T & P variations
- (f) after carbon has reached  $100^{\circ}\text{C}$  and all of the CuAA has been adsorbed, set temperature for  $180^{\circ}\text{C}$
- (g) keep carbon temperature between  $180^{\circ}$  and  $190^{\circ}\text{C}$  until pressure drops, indicating decomposition is almost complete; then set temperature for  $275^{\circ}\text{C}$  to finish the reaction.
- (h) when pressure begins to drop at  $275^{\circ}\text{C}$ , turn off heat and allow carbon to cool down below  $100^{\circ}\text{C}$
- (i) restore system to atmospheric pressure and weigh carbon

From the initial carbon weight, final carbon weight and weight of CuAA used, the percentage completeness of the decomposition reaction can be calculated. If the above procedures are followed, the reaction will be better than 90% complete, and very little CuAA will be lost through sublimation. Because the rate of decomposition is rather slow below  $200^{\circ}\text{C}$ , however, this procedure requires a relatively long reaction time. A 150 gm sample of carbon to be impregnated 4% by wt with copper required about 7 hrs by this method. Time requirements can be reduced considerably by ignoring step 2 and raising the temperature up to  $275^{\circ}\text{C}$ , however, as much as 20% of the CuAA will be lost through sublimation.

FIGURE II



COPPER DEPOSITION APPARATUS

## CrO<sub>3</sub> IMPREGNATION

As a result of difficulties involved in oxidizing chrome from the metal to the +6 state, it was decided to postpone examination of deposition processes involving dicumene chromium in favor of the more direct chromyl chloride vaporization and CrO<sub>3</sub> sublimation methods. Even with chromyl chloride, a hydrolysis step is necessary to produce the +6 oxide, thus initial experiments were performed using CrO<sub>3</sub>.

Experience with copper impregnation from CuAA had taught that materials with low vapor pressure such as CrO<sub>3</sub> must be brought in close initial contact if vapor impregnation is to be achieved. As a result dry CrO<sub>3</sub> was mixed with outgassed carbon in the same manner as CuAA for copper impregnation, [See Fig. 2] a vacuum drawn, and the material heated. Several runs were made using this method with each run having a different ultimate sublimation temperature [Table 1]. Analysis of the carbon after each run showed in all cases that little or no chromium had been adsorbed by the carbon. Pressure rises noticed above 150°C during impregnation indicated also that reduction of the CrO<sub>3</sub> which did adsorb on the carbon was occurring, with the production of CO<sub>2</sub>. These results showed that CrO<sub>3</sub>, unlike CuAA, has little or no tendency to adsorb on carbon. Carbon samples were impregnated with ammonia and water in an attempt to increase the affinity of carbon for CrO<sub>3</sub>. Samples for this run were tested for CrO<sub>3</sub> by treating them with water to dissolve off any CrO<sub>3</sub> and adding lead nitrate. Only a small amount of yellow ppt. was seen, indicating that very little CrO<sub>3</sub> had been adsorbed. This combined with the low vapor pressure of CrO<sub>3</sub> and its ease of reduction to Cr<sub>2</sub>O<sub>3</sub> at elevated temperatures, ruled out vacuum sublimation as a method of vapor impregnating carbon with CrO<sub>3</sub>.

The next method tried involved the use of chromyl chloride CrO<sub>2</sub>Cl<sub>2</sub>, a dark red liquid, which boils at 117°C. This material may be converted to CrO<sub>3</sub> by water or any other compound capable of replacing the chlorine in chromyl chloride with oxygen.

The first experiment with chromyl chloride consisted of vaporizing the material under vacuum, into copper impregnated carbon placed in a glass tube. This run showed that carbon has a strong affinity for CrO<sub>2</sub>Cl<sub>2</sub> as a large amount of the compound was adsorbed by the carbon, and heat was generated during the adsorption. Having saturated the carbon with CrO<sub>2</sub>Cl<sub>2</sub>, water vapor was passed through in order to hydrolyze the CrO<sub>2</sub>Cl<sub>2</sub> to CrO<sub>3</sub>. Once again heat was generated. Analytical tests performed on the material from this experiment indicated that some of the chrome had been reduced to the +3 state, and some of the copper had been converted to CuCl<sub>2</sub>.

In order to prevent the unwanted conversion of CuO to CuCl<sub>2</sub>, NH<sub>4</sub>OH was tried as a means of tying up the chlorine. Runs made by this ammonolysis treatment also yielded heat and showed some reduction of chromium to the +3 state, however, no CuCl<sub>2</sub> was detected. Finally, an ice water bath was used to reduce the heat generated during the

TABLE I EXPERIMENTAL PARAMETERS FOR VAPOR IMPREGNATION OF CARBONS

RUN NO.	METAL COMPOUND	SYSTEM FIGURE NO.	CARBON TEMP °C	REACTANT	DEP. PRESSURE		WT %	RESULTS
					MILLIMETERS			
1	CuAA	1	330	--	2	--	--	CuAA decomposed in vaporizer & condensed on reactor walls.
2	CuAA	1	260	--	0.25	--	--	Heated walls & lower pressure failed to prevent condensation of CuAA.
3	CuAA	2	260	--	0.5	8	8	Analytical tests showed presence of Cu although most CuAA remained unreacted.
4	CuAA	2	300	--	0.3	8	8	Higher final temp & longer reaction time produced 75% conversion of CuAA to Cu.
5	CuAA	2	275	--	0.3	7	7	Used final procedure for CuAA conversion, reacted 90% complete.
6	CrO <sub>3</sub>	2	180	--	0.2	-	-	Only a small amount of CrO <sub>3</sub> found on carbon
7	CrO <sub>3</sub>	2	200	--	0.08	-	-	Same as 6 with some +3 chrome found
8 (a)	CrO <sub>2</sub> Cl <sub>2</sub>	Straight Tube	80	H <sub>2</sub> O	5	-	-	Some +3 chrome & some CuCl <sub>2</sub> most Cr & Cu on carbon in water insoluble form.
8 (b)	CrO <sub>2</sub> Cl <sub>2</sub>	Straight Tube	80	NH <sub>4</sub> OH	5	-	-	Some +3 chrome - no CuCl <sub>2</sub>
9	CrO <sub>2</sub> Cl <sub>2</sub>	Straight Tube	60	NH <sub>4</sub> OH	1	2	2	Slow addition of reactants keep down heat & formed little +3 Cr.
10	CuAA	2	275	--	0.3	4	4	Sample sent to Edgewood Arsenal (EA) 94% conversion.
11	CuAA	Straight Tube	60	NH <sub>4</sub> OH	Atmos.	-	-	Carbon from run 15 saturated with NH <sub>4</sub> OH for Cr dep. runs 12 & 13.
12	CrO <sub>3</sub>	2	155	Carbon from run 11	0.2	2	2	Analytical tests showed little Cr on carbon. Sample sent to EA.
13	CrO <sub>2</sub> Cl <sub>2</sub>	3	150	Carbon from run 11	0.4	2	2	Used final procedure for Cr dep. Sample sent to EA.
14	CuAA	2	275	--	0.3	2	2	95% conversion. Sample sent to EA.
15	CuAA	2	275	--	0.3	1/2	1/2	95% conversion. Sample sent to EA.

reaction from getting excessive. Tests made on samples from this run showed no reduction of +6 chrome, and no formation of  $\text{CuCl}_2$ .

From these results, the following method for the deposition of  $\text{CrO}_3$  was adopted:

- (a) Place previously copper impregnated carbon into flask shown in Fig. 3 and evacuate.
- (b) When pressure drops below 500u close valve A and open valve B to allow  $\text{NH}_4\text{OH}$ , or any other compound capable of exchanging an oxygen atom for the chlorine atoms, to enter the reaction flask and impregnate the carbon.
- (c) When impregnation is complete (about 3 minutes), close valve B and open valve A to sweep out excess reactant.
- (d) When pressure drops below 1000u, close valve A and open valve C to allow  $\text{CrO}_2\text{Cl}_2$  to enter flask and impregnate carbon.
- (e) When the amount of chromyl chloride necessary to give the desired wt. % of  $\text{CrO}_3$  has been vaporized, close valve C and open valve A to remove products.
- (f) After the pressure drops below 1000u, close valve A and open valve B to complete the conversion.
- (g) When reaction is complete (about 3 min) remove ice water bath, close valve B and open valve A. When pressure drops below 500u shut off pump and restore system to atmospheric pressure.

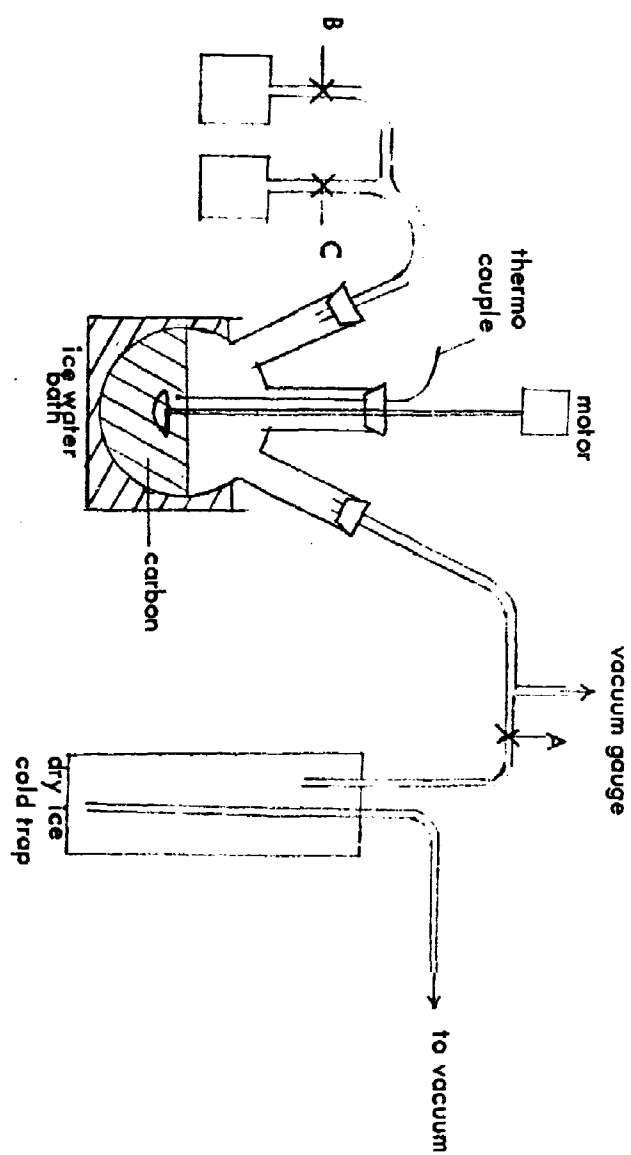
#### PREPARATION AND TESTING

Analytical test performed on samples prepared by the above mentioned vapor impregnation procedures showed that these procedures deposited copper and chrome on carbon in the desired form and with high efficiency. Therefore, nitrogen adsorption isotherms were performed on samples of untreated carbon and samples from runs #5 and #13 to determine changes in surface area of the carbon caused by the impregnation. These test showed that an 8% by wt copper impregnation causes a 15% reduction in surface area from 1125 sq. m/pgm the untreated carbon, to 452 sq m/gm for the impregnated sample. Adsorption isotherms for samples from run #13 indicated that 2%  $\text{CrO}_3$  impregnation along with the 8% copper lowers the surface area another 17% to 764 sq m/gm.

Samples from runs #12 and #13, containing copper and  $\text{CrO}_3$ , were sent to Edgewood for CK and PS break through testing. In all cases, the vapor impregnated samples showed shorter break through time than the untreated carbon. Tests with chloropicrin (PS) which is removed by physical adsorption rather than catalyzed decomposition, showed a 32% reduction in wt percent adsorbed. This is consistent with the fact that there was also a 32% reduction in surface area, as calculated from nitrogen adsorption isotherms by the BET equation for the vapor impregnated samples. As a result, samples from run #10, a 4% by wt copper impregnation,



FIGURE III



CHROMIUM DEPOSITION APPARATUS

were tested for PS break through times. These samples showed times equal to that of untreated carbon, indicating an insignificant drop in surface area with this degree of loading.

### CONCLUSIONS AND RECOMMENDATIONS

Vapor impregnation methods can be used to deposit catalysts within the pores of activated carbons. Results of nitrogen adsorption isotherms and PS break through tests on 8% by wt Cu impregnate indicates, however, that considerable reduction in surface area is produced by this high loading. The 4% by wt impregnate does not show this loss of surface area, therefore, this concentration will be used for future impregnation.

Although analytical tests indicate that copper and chrome are present on the vapor impregnated carbon in the same oxidation states as on the ASC whetlerite, CK break through tests showed no significant catalytic activity for the vapor impregnated sample. Future work in this phase will be devoted to varying the catalyst deposition and activation procedures in order to produce impregnated carbons with CK activity.

## BIBLIOGRAPHY

1. NDRC Div. 10 Summary Report, P. 73
2. U. S. Patent #2,704,728 gas plating metal objects with CuAA
3. U. S. Patent #3,203,827 chromium plating process
4. R. W. Granston, *Advances in Catalysis* 9:143 (1957)
5. S. Brunauer, P. Ennett, E. J. Teller, *Am. Chem. Soc.*,  
60, 309 (1938)

\*Bed Area is 2.93 cm<sup>2</sup>.

# APPENDIX EDGEWOOD ARSENAL BREAKTHROUGH TIME TESTS FOR VARIOUS IMPREGNATED CARBONS

Sample No.	Date	Inlet Conc. mg/L	Volume Flow L/min.	Linear Velocity cm/min	Carbon Volume cm <sup>3</sup>	Carbon Weight g	Relative Humidity	Temp of	Protective Life Min.	As is corrected	Bed Depth cm.	Gas
Control												
8425C PCC	3/12/69	4.12	1.675	575	15	6.10	80	80	5.6	5.77	5.2	CK
9425C PCC	3/12/69	4.12	1.675	575	15	5.91	80	80	5.5	5.66	5.2	CK
8425C PCC	3/12/69	4.08	1.675	575	30	11.40	80	80	23.2	24.6	9.9	CK
8425C PCC	3/12/69	4.27	1.675	575	30	12.3	80	80	24.7	25.2	11.0	CK
8425C PCC	3/12/69	4.08	1.675	575	7.5	2.73	80	80	1.5	1.5	2.4	CK
8425C PCC	3/12/69	4.08	1.675	575	7.5	2.72	80	80	1.5	1.5	2.4	CK
8425C PCC	3/12/69	4.08	1.675	575	22.5	9.56	80	80	14.4	14.63	8.4	CK
8425C PCC	3/12/69	4.08	1.675	575	22.5	8.87	80	80	12.2	12.67	8.5	CK
11- 12 - 3/5 P-1 (8)Cu(3)Cr	3/18/69	4.28	1.68	575	10.0	5.22	80	84	1.7	1.8	3.9	CK
11- 12 - 3/5 P-1 (8)Cu(3)Cr	3/18/69	4.28	1.68	575	10.0	4.65	80	84	1.9	2.0	3.9	CK
11- 12 - 3/5 P-1 (8)Cu(3)Cr	3/18/69	49.88	1.07	365	10.0	5.37	0	-	32.0	32.1	3.6	PS
11- 13 - 3/6 P-1 (8)Cu (2)Cr	3/18/69	4.28	1.68	575	10.0	5.24	80	84	1.1	1.18	4.0	CK
11- 13 - 3/6 P-1 (8)Cu(2)Cr	3/20/69	4.28	1.68	575	10.0	4.85	80	84	1.0	1.07	3.9	CK
Control												
8425C PCC	3/20/69	49.88	1.07	365	10.0	3.76	0	-	36.4	39.2	3.4	PS
Control												
8425C PCC	3/20/69	49.88	1.07	365	10.0	2.51	0	-	17.2	19.5	2.3	PS

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

25

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Impregnation Vapor Phase Active carbons Metals Metal salts Toxic gas removal Copper disposition CWS carbon Ammonolysis Hydrolysis Chromyl chloride Spectrographic analysis						